

**AT&T WIRELESS SERVICES, INC.**  
**TECHNICAL APPENDIX**  
**IB Docket No. 01-185, ET Docket No. 95-18**

**Technical Discussion of Spectrum Sharing Between the Mobile Satellite Service and  
Terrestrial Wireless Services in the 1990-2025/2165-2200 MHz Bands**

**Introduction**

From analyses provided to the Commission by CTIA, Cingular Wireless, Sprint PCS, New ICO Global Communications (“ICO”), and Globalstar, L.P., it is readily apparent that there is broad agreement among all parties that segmentation of the 1990-2025/2165-2200 MHz band (“2 GHz band”) is technically possible and that the band could be divided between mobile satellite service (“MSS”) and terrestrial operations.

Although ICO and Globalstar contend that they would be able to share, on a co-channel basis, spectrum between satellite and terrestrial operations, an examination of their technical filings makes clear that there is no empirical support for this proposition. First, notwithstanding their claims to the contrary, “dynamic frequency coordination” would not markedly reduce the level of harmful interference between the handset when operating in the ancillary terrestrial component (“ATC”) mode and the MSS uplink because the satellite still would capture and aggregate adjacent channel interference. Moreover, neither ICO nor Globalstar has demonstrated that it actually could design and deploy a terrestrial system that is capable of repeated frequency hops on a real-time basis for every base station within a million-square kilometer, moving satellite beam.

Second, ICO’s and Globalstar’s contentions that spectrum sharing would not be problematic because they would confine their ATC subscribers to urban cores is based on the faulty assumption that virtually all city users would be completely blocked from the satellite. While urban coverage may not be optimal, there is no technical basis to believe that all callers would be deep inside buildings or surrounded by skyscrapers. Furthermore, signal attenuation for MSS indoor use is a problem not just in urban environments, but in rural areas. Indeed, the ATC proponents’ technical filings demonstrate that to serve rural customers adequately, they would have to deploy thousands of terrestrial base stations in *all* areas of the country. Not only does this undermine ICO’s and Globalstar’s claims that they can serve rural areas through MSS alone, it increases significantly the potential for interference between the ATC handset and the MSS uplink within one satellite beam.

Finally, even if the “dynamic” spectrum sharing contemplated by ICO and Globalstar were technically possible, there is no technical limitation on the provision of such dynamic sharing by a third party unrelated to the satellite entity. Rather, any dynamic spectrum sharing would entail a requirement for satellite and terrestrial operations to be coordinated between the disparate uses.

## Technical Summary

A review of the technical analyses provided by the terrestrial wireless proponents (CTIA, Cingular Wireless and Sprint PCS) and the ATC proponents (ICO and Globalstar) indicates consistently that the area of major concern for interference mitigation is the interference that will occur between the ATC mobile unit and the MSS uplink. The extensive technical calculations on the record demonstrate that the three other interference scenarios (MSS terminal to the ATC uplink, ATC base to MSS downlink, and MSS spacecraft to ATC downlink) are confined primarily to the areas near the edge of the MSS/ATC coverage boundaries and would be manageable, either by third parties or existing satellite licensees, with strict control of power between the satellite and terrestrial operations. ICO's and Globalstar's most recent filings appear to attempt to show that the MSS terminal to ATC uplink scenario is more problematic, but it is clear from the Telcordia analysis, even with the additional EIRP proposed by ICO for the MSS terminals, that this interference case can still be accommodated.

In the analysis of interference effects between an ATC mobile and the MSS uplink, any and all energy radiated by an ATC mobile will be cumulatively collected by the spacecraft receiver, meaning that rather than being manageable, each additional, co-channel ATC mobile will have a steadily more destructive effect on the margins of the MSS operation. Regardless of whether a third party or an MSS operator provided the ATC service, this interference effect would multiply without shielding of the ATC mobile unit from the satellite spacecraft. Thus, the limit on the number of ATC mobile units available for operation within the beam of the MSS system is fixed and limited, even by the ATC proponents' calculations, to no more than a handful of mobiles. From a technical standpoint, it is unclear what the benefit of adding an extremely small number of additional terrestrial users to an existing MSS system, on a co-channel sharing basis, would provide. Any co-channel sharing would require expensive and complicated sharing mechanisms to be utilized with very little corresponding economic or efficiency gain for the underlying MSS network. Rather, it would have an aggregate effect of destructive interference to the underlying network, in a co-channel sharing scenario.

In contrast, if spectrum segmentation were envisioned, the technical analysis simply requires an adjacent channel interference mitigation requirement. Such adjacent channel mitigation techniques are well-known and used extensively. Further, adjacent channel interference alleviation would allow for the construction and deployment of a robust, spectrally-efficient terrestrial network that would take full advantage of the inherent efficiencies associated with standard terrestrial wireless networks. Additional terrestrial mobile units would not have a destructive effect on MSS operations, and simple emission mask requirements would be placed on terrestrial mobile and base station units to protect the adjacent channel operations of the MSS. In fact, such segmentation is the most technically sound approach and provides for better spectrum use and efficiency, while eliminating undue complexity and costs associated with a co-channel sharing situation, such as dynamic frequency management.

ICO's and Globalstar's technical filings demonstrate that they understand fully the problems of spectrum sharing; indeed, they both admit that they intend to segment the spectrum themselves and assign non-overlapping channels to the terrestrial and satellite systems. Nevertheless, in an attempt to support their claims that only existing MSS licensees can efficiently provide both services, they assert that they will employ "dynamic spectrum sharing," which theoretically will allow the licensee to move channels from one use (and therefore, one segment) to another on a real-time, as-needed basis. Because spectrum sharing, dynamic or otherwise, raises significant interference concerns for the MSS system, however, the ATC proponents say that they will deploy an untested mechanism called "dynamic frequency coordination," which purportedly will allow the licensee to eliminate co-channel terrestrial use in the satellite beam. As described more fully below, the effectiveness of using dynamic frequency coordination as an interference mitigation technique is highly questionable. Because only a very few ATC mobile units can be used within a satellite beam simultaneously, large numbers of ATC base stations within the million-square kilometer, traveling beam would be required to change frequencies constantly and quickly based on control signals indicating MSS use on a particular channel. No system, terrestrial or satellite, in operation today is capable of this level of dynamic response. Moreover, even if it were technically feasible to remove all co-channel ATC energy from the satellite footprint without causing debilitating degradation to the terrestrial operations, the ATC proponents fail to take into account that the spacecraft receive antenna would still readily capture and aggregate adjacent channel interference from ATC operations. Accordingly, the number of ATC mobile units that could be used on a dynamic channel sharing basis with MSS operations remains almost as small as the number that could be used on a non-dynamic channel sharing basis.

### **Technical Analysis**

*Downlink interference to ATC or MSS Mobile Units.* A mobile unit, whether utilizing the terrestrial (ATC) or an MSS downlink in a co-channel sharing model, will receive signal power from both the MSS spacecraft and the ATC base stations. The MSS spacecraft signal strength as measured at the Earth within a transmit beam will be relatively constant. However, the signal strength received from an ATC base station will vary greatly dependent on the power used by the ATC base station and the distance from the base station. The key efficiency in frequency reuse for terrestrial networks takes advantage of this possibility, by reusing frequencies with appropriate geographic and power separation throughout a service area. In light of this dynamic, a mobile unit operating near an ATC base station, or even at some distance to a higher powered ATC base station,<sup>1/</sup> would be unable to obtain the MSS downlink signal. Therefore, in these areas, the mobile unit would consistently select the ATC signal for its operations.

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<sup>1/</sup> Typically, an ATC base station could be expected to be higher powered in a rural setting where system capacity is not the driving concern, as opposed to an urban environment. In an urban market, capacity of the system is the key factor, so multiple, low powered base stations are normally utilized to enhance frequency reuse.

At the edges of the ATC coverage area, the MSS downlink signal would dominate the ATC base station signal, forcing the mobile unit to consistently choose the MSS spacecraft downlink for its service operations. However, there will be a significant region of area where the ATC and MSS downlink signal strengths are comparable, where each signal would therefore present interference effects to the other. In this region, similar to the handoff region for terrestrial network, special technical handling of the communications link would be necessary. Furthermore, this interference mitigation/handoff requirement will differ between CDMA and FDMA/TDMA networks, the types of networks to be deployed by Globalstar and ICO respectively. Nonetheless, if, as stated by the ATC proponents, ATC is simply to be used for truly “ancillary” coverage, the expectation is that the MSS downlink signal would be blocked or significantly limited in any area an ATC is to be deployed. Moreover, through well-settled engineering practices, there are methods of implementing ATC to ensure that seamless, interference-free coverage is provided in these mitigation zones.

*Interference to an ATC Base Station from an MSS Mobile.* A co-channel mobile station, operating in the MSS mode, will interfere with the ATC base station receiver dependent on the distance from the MSS mobile to the base station and the power used by the mobile. For MSS mobile uplink operations, power levels will be relatively constant, but at a much greater strength than an ATC mobile attempting to communicate with an ATC base station. This is true because of extensive distance, and therefore path loss, associated with the communication link between the MSS mobile and the MSS spacecraft as compared to the distance between an ATC mobile and an ATC base station. Therefore, an MSS terminal operating at the edges of an ATC service coverage area can provide significant interference to the ATC base station. The interference caused to the ATC base station would diminish the capacity of the ATC system.

However, this interference effect would be expected to be extremely infrequent due to the known system parameters of an MSS system and to the proposed implementation of a co-channel ATC system by the ATC proponents. From the calculations provided by Cingular/Sprint PCS/Telcordia, there is on average approximately one active MSS mobile unit for every 200 ATC service areas. From simple probability theory, assuming a random distribution of MSS mobile units, the probability that an MSS mobile unit is within one coverage area radius of the edge of a given ATC coverage area is extremely low. Furthermore, ATC proponents have indicated that the deployment of ATC systems would only occur in areas where there was a lack of MSS coverage, further limiting the probability that harmful interference would occur in this scenario. The modeling provided by Telcordia clearly demonstrates that only if MSS mobile units were aggregately clustered near ATC coverage area boundaries would MSS-to-ATC uplink interference become a significant problem. Neither Globalstar nor ICO have rebutted this fundamental point. Regardless of the EIRP increase to 5 watts as indicated by ICO, the Telcordia model clearly considered that the EIRP may fluctuate. In fact, if the majority of ATC coverage will be urban micro and picocells,<sup>2</sup> then the Telcordia modeling

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<sup>2</sup> See June 13, 2002 ICO Filing at 6.

demonstrates that the interference effect would be even less severe.<sup>3</sup> Clearly, the interference model provided by Telcordia accurately demonstrates that the interference case of MSS handsets to ATC base stations is not of major concern.

*Interference to MSS Uplink from ATC Mobiles.* In direct contrast to the other interference scenarios, the MSS spacecraft will be adversely affected by ATC mobiles operating on a co-channel basis within the beam of the receive antenna. This is true because the MSS spacecraft antenna is seeking *any* co-channel carrier within the beam of the antenna. Thus, any ATC mobile operating co-channel would be “seen” by the MSS spacecraft. Certainly, the MSS system has provided a margin in the uplink budget to protect against spurious co-channel interferers; however, each additional co-channel ATC mobile unit within the spacecraft receive beam will degrade this margin in a cumulative fashion. Therefore, the MSS uplink interference will be the sum of all the power levels received from any in-beam, co-channel ATC mobile units. This increase in the power levels from ATC mobile units will increase the noise floor for the MSS spacecraft receiver, eliminating channels that can be used for MSS operations. The dynamics for the air interfaces used by the ATC proponents (CDMA and FDMA/TDMA) are different, but the end result of lost capacity is exactly the same.

Globalstar attempts to refute this point by relying on approximately 27 dB of radio link terms that, in its opinion, mitigates the effects of ATC operations. Globalstar’s analysis is flawed in a number of respects. First, Globalstar has not provided information on the derivation of each of its “average” numbers. For example, Globalstar contends that the average MSS handset EIRP in the direction of the serving satellite is 22.4 dBm without further discussion of this value’s origination. Furthermore, the use of the Hata model is at best an approximation, and at worst wrongly applied to frequencies above 2 GHz. The ITU recommendation noted by Globalstar covers frequencies up to 2 GHz.<sup>4</sup> However, the MSS frequencies under consideration exceed 2 GHz, in many instances. Moreover, this recommendation has since been withdrawn.<sup>5</sup> Even if the application of the Hata model is appropriate, Globalstar has not derived its application of an “average” 10.5 dB propagation loss. Finally, it cannot be accepted that each of the factors cited by Globalstar are linear, and therefore additive. Although each attenuation factor presented is described as an average value, it is unclear that each of these attenuation amounts would occur in a simultaneous fashion. Therefore, simply aggregating these values to arrive at a new value for the number of simultaneous ATC users is inappropriate.

The interference effects felt at the spacecraft receiver from the ATC mobile unit are dictated by the power level utilized by the ATC mobile, the free space path loss to the spacecraft, the gain of the antenna used by the spacecraft, and any blockage or other signal attenuation between the ATC mobile and the spacecraft. An ATC mobile unit’s

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<sup>3</sup> See Telcordia Appendix at 36.

<sup>4</sup> See ITU-R P.529-3, *Prediction Methods in the Terrestrial Mobile Service in the VHF and UHF Bands* at 7.

<sup>5</sup> See <http://www.itu.int/rec/recommendation.asp?type=folders&lang=e&parent=R-REC-P.529> (last viewed July 8, 2002).

power will vary dependent on the distance from the ATC base station it is communicating with (especially in the CDMA air interface). Blockage and signal attenuation will be dependent upon the location of the ATC mobile unit with respect to the spacecraft. For example, if the ATC mobile is operating within a building, significant signal attenuation with respect to the spacecraft would be expected. Additionally, the elevation angle of the spacecraft with respect to the ATC mobile is blocked by a building, significant blockage of the ATC signal is to be expected. However, free space path loss and the spacecraft antenna gain would be approximately constant in a particular spacecraft/ATC mobile link budget calculation.

Telcordia's calculations were extremely enlightening with respect to the effect that an ATC mobile would have on a CDMA uplink. In the calculations provided, only an aggregate 1 watt of EIRP from ATC mobile units to a CDMA MSS spacecraft would cause a channel availability reduction of more than 10 percent. To put this into perspective, a terrestrial wireless mobile unit can be expected to typically radiate approximately 100 mW, meaning that only ten such units could severely affect the MSS uplink in an enormous coverage area. In fact, only eighty ATC mobile units would be required to completely shut down an MSS uplink in an affected beam.

This analysis demonstrates that in order for a co-channel, spectrum sharing, ATC/MSS system to operate properly, implementation of the ATC would need to ensure that each ATC mobile unit was heavily blocked from the MSS spacecraft within the beam of the MSS receiver. From a technical and operational standpoint, this would require that the subscribers to the service be limited to operating their mobile units only deep within buildings or when surrounded by skyscrapers while in the ATC mode. It is unclear how a service provider could, or would want to, restrict the operations of its subscribers in this fashion.

If ICO's and Globalstar's assertions with regard to satellite blockage "prove" anything, it is that MSS signal attenuation is also a problem for indoor *rural* use. Specifically, if an MSS customer is attempting to make a call from the first floor of his home, there would be significant contributory signal losses from a single wall and a single floor.<sup>6/</sup> At 1300 MHz, this would translate into losses of better than 40-50 dB. Although measurements for the 1900-2200 MHz bands are not currently reported, it is clear that the loss would be at least 40-50 dB, if not more. With signal attenuation reaching these levels, MSS providers would not be able to provide adequate service to rural customers (except perhaps those who only want to talk while outside) without extending their ATC networks far into rural areas. This, in turn, would compound the ATC mobile/MSS uplink interference problems, as well as raise serious doubts about ICO's and Globalstar's claims that they are better equipped to serve rural areas than solely terrestrial carriers.

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<sup>6/</sup> See Wireless Communications Principles and Practices, Theodore S. Rappaport, copyright 1996 (Prentice Hall), at 24.

*Dynamic Frequency Coordination.* While ICO and Globalstar recognize that co-channel use is not feasible due to interference from the ATC mobile units to the MSS uplink, they contend that they can share channels between the MSS and ATC operations on a real-time basis through “dynamic frequency coordination.” According to ICO and Globalstar, dynamic frequency coordination would allow licensees to eliminate all co-channel, in-beam frequency use. This would entail control signaling, in a real-time fashion, between the MSS and ATC networks to prevent a terrestrial system within a satellite beam footprint from operating on frequencies being used by the satellite in the beam. Apparently, frequency usage would be assigned based on the capacity requirements of the satellite beam and the ATC cells within the beam footprint.

Even if dynamic frequency coordination were technically feasible (which, as discussed below, is dubious) it would do very little to protect the MSS system from interference. This is because of the lack of clear signal boundaries from satellite and ATC transmissions and the new *adjacent* channel interference effects of the ATC operations on the MSS system.. As anyone who has studied the beam antenna pattern from a satellite antenna can tell, the pattern certainly is not “smooth.” Therefore, even though care would be taken to remove co-channel energy (interference) from the operations of the ATC to the MSS system, the spacecraft receive antenna would still readily capture and aggregate the power from ATC transmissions on adjacent channel frequencies, with some rolloff. While the use of geographic separation would help alleviate the power levels seen by the spacecraft receive antenna, sufficient interference from adjacent area, co-channel ATC operations would nevertheless be accumulated to cause interference to the MSS uplink. Additionally, even if the terrestrial handsets and the MSS uplink are geographically separated, ATC mobiles operating within the antenna beam of the MSS spacecraft may still cause adjacent channel interference to the MSS uplink. The severity of the adjacent channel interference would be solely limited to isolation between the adjacent frequency channels. Thus, while the ATC proponents are the only entities with complete knowledge of the spacecraft antenna patterns and MSS system adjacent-channel isolation requirements, an analysis of their technical proposals shows that, even with dynamic spectrum management, very few ATC mobile units can be tolerated within a spacecraft beam footprint without destructive, harmful interference to the MSS system.

Furthermore, it is far from clear that such a dynamic system is practical in application. As ICO’s and Globalstar’s technical analyses show, dynamic frequency coordination would entail constant and rapid frequency changes to large numbers of terrestrial base stations within the spacecraft beam. This would be dictated by the movement of the spacecraft beam coverage across the surface of the earth and would be extremely disruptive to the CDMA systems both ICO and Globalstar intend to deploy. In particular, communications over CDMA networks entail the acquisition of a pilot and other overhead channels as well as the establishment of power control parameters, and each of these system requirements would have to be reacquired repeatedly and expeditiously for the dynamic frequency coordination model to work. And, even if these complicated and untested procedures could actually be implemented, it is readily apparent that service quality would be significantly degraded, with an unacceptable increase in the number of dropped calls. As such, from a technical standpoint, dynamic frequency coordination to

enable frequency sharing appears to have virtually no benefit for increased efficiency in spectrum use, while introducing a variety of complications to the system operation that, if deployable at all, would severely degrade the quality of service received by subscribers.

### **Conclusion**

From review of the technical information provided to the Commission, it is clear that any extensive use of terrestrial services in the 2 GHz band would require band segmentation between satellite and terrestrial services. Dynamic frequency sharing, or other methods of co-channel frequency sharing, would not result in significant gains in efficiencies and would introduce extensive complications and degradation to the quality of service for both the terrestrial and satellite networks. In addition, neither ICO's nor Globalstar's technical analysis demonstrates that provision of terrestrial service in the 2 GHz band, whether through hard spectrum segmentation or dynamic frequency sharing, could only be offered by the satellite provider. To the contrary, their filings highlight only that grant of their dynamic sharing ATC proposals would result in severe economic and operational difficulties.